Disc swirl spinning — A novel approach

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A new spinning method ‘disc swirl spinning’, which consists of a combing roller drafting device, funnel fibre conveyer, disc fibre collector and swirl twister, has been developed. The spinning process, the design of the mechanism and its applications have been described and a preliminary comparative performance of the yarn quality analyzed. Scanning electron microphotographs of the disc swirl core-spun yarn have been compared with those of the air-jet spun and rotor-spun yarns. It is observed that the appearance of disc swirl core-spun yarn is similar to that of rotor-spun yarn, while the inner structure of the disc swirl core-spun yarn is found similar to that of the air-jet spun yarn. The breaking strength of disc swirl core-spun yarn is little lower than that of the ring core-spun yarn, while its breaking elongation CV% is higher. The other quality parameters of the two kinds of yarn are found to be similar. The quality of the disc swirl core-spun yarn can basically meet the need of the processes.

Keywords: Air-jet spinning, Combing roller drafting, Core-spun yarn, Disc fibre collector, Disc swirl spinning, Funnel fibre conveyer, Swirl twister

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1 Introduction

Air-jet has been widely used to process fibres in textile, such as interlacing process and air-jet spinning. Among the new spinning systems, air-jet spinning is favoured for its special capability of fine yarn production at high speeds. To achieve these capabilities, the rubber-covered rolls of air-jet spinning machine have to rotate at a high speed under high pressure during the spinning process. This causes the rubber-covered rolls to wear quickly and the power consumption is also high. According to industry experience, the average service life of common rubber-covered roll is only one week, and that of the Teijin special rubber-covered roller is only one and a half month. Moreover, the highest drafting speed of air-jet spinning is still much lower than the capability of rapid production possible using the high rotation speed of jet stream in nozzle (5×10^5~1×10^6 r/min) (ref.4). Thus, the development of air-jet spinning is limited by the large consumption of components and power.

Therefore, it is put forward for the first time to combine combing roller drafting system with air swirl twister. A new disc swirl spinning method has been developed, that uses air-jet to process fibres and aims to resolve the problems existing in air-jet spinning. In addition to designing a funnel-shaped fibre conveyer, a disc fibre collector and a swirl twister, a combing roller rotating at a high speed has also been designed to substitute the drafting roller in air-jet spinning. The characteristics and applications of this novel spinning system have been described and the performance of yarns produced by disc swirl spinning machine compared with that of other spinning systems.

2 Materials and Methods

Combed strand of cotton fibres (2.68 g/m), and polyester FDY 55 dtex/24f (breaking elongation 11.4%, tensile strength 6.6 cN/tex) were used as raw materials for producing a core-spun yarn on this newly developed spinning system.

2.1 Disc Swirl Spinning

The disc swirl spinning machine (Fig.1) can be utilized to produce either normal yarn or core-spun yarn. The normal yarn is produced when the core filament yarn (5) is stopped being fed. When cotton sliver comes to the feeding device, it is held and fed successively into combing roller drafting system (1), funnel-shaped fibre conveyer (2), and disc fibre collector (3) to be drawn and combined into a strand and reduced to much thinner size than the original sliver. Then, the thinner sliver is fed into front nip which is formed by disc fibre collector (3) and pressing roller (9). Fibres from front nip are fed into

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At the same time, the filament yarn (5) is pulled from stand (4) and fed into swirl twister (10) by front nip, passing through tension device (6), filament yarn guide (7), and guide (8) in turn. In swirl twister (10), staple fibres are twisted around the filament yarn, and core-spun yarn (13) is formed, which is then pulled through yarn guide (11) by leading roller (12). In the end, yarn package (15) is formed with rotation of grooved drum (14).

The mechanism of disc swirl spinning is shown in Fig. 2 and the spinning principle is described below. When the sliver is concentrated by funnel (1), it goes into the holding area formed by feeding roller (3) and feeding board (2), where the sliver is grasped evenly by the nip of feeding device under the pressure of spring (4), and moves forward with the rotation of feeding roller (3). Once the combing roller (5) rotating at a high speed seizes the sliver on the feeding board, the fibres in the sliver are blended, straightened out and separated gradually under the action of both sawtooth and difference of the air pressures on the surface of combining roller. Finally, fibres are peeled off and flown into funnel-shaped fibre conveyer (7) by suction, which makes the average speed of airflow increase gradually along the conveyer. Fibres get straightened out in airflow. The funnel-shaped fibre conveyer connects with disc fibre collector (8), the surface of which is an eyeleted groove that can rotate. The inner part of the disc is a fixed fan-shaped air duct, which connects with a negative pressure suction system. Fibres from funnel-shaped fibre conveyer (7) are absorbed by suction in turn on the eyeleted groove, which rotates on the surface of disc fibre collector (8). Along with the rotation of the eyeleted groove, the fibres in the groove are blended and arranged in parallel order, meeting nearly end to end. When the groove rotates to the point where the groove meets with pressing roller (9), the suction ends. At this moment, leading ends of fibres stretch out from the point under the action of pressing roller (9), thus becoming free. Under the limitation of the form of groove, the strand of fibres is drawn into swirl twister (11) by suction, and is twisted by swirling air. The swirl twister is made up of two nozzles, namely the first nozzle and the second nozzle that connects with the first. The airflows in the two nozzles rotate in opposite directions, and the rotation rate in the second nozzle is larger than that in the first nozzle. The strand of fibres gets twisted under the action of the two airflows in opposite directions.

2.1.1 Combing Roller Drafting System

The novel drafting device is a combing roller drafting system, which is designed using the operating principle of the drafting device of rotor spinning. As shown in the left half of Fig. 2, it is made up of feeding device, combing roller, and other parts.

Feeding device consists of funnel, feeding board, feeding roller and pressure spring. A nickel alloy with large friction coefficient is used as the cover material of the feeding roller, and the surface of feeding board is electroplated and smooth. In this way, coefficient of friction between the feeding board and the sliver is ensured to be smaller than that between fibres. This feeding device not only ensures that the sliver passes through feeding board smoothly and evenly, but also prevents sliver from slicing.

To achieve super draft, a comblike roller ‘combing roller’ is used. Its angle of sawtooth is 12° and rotation speed is 12000 rpm. It can arrange fibres into parallel form at a high rotational speed.
As compared to the traditional drafting device of rotor spinning, this design is improved in the following manner: (i) it adds independent control apparatus of the rotations of combing roller and feeding roller to control yarn count, (ii) it enlarges the size of combing roller to permit high operation speed and super draft, (iii) it redesigns the form and angle of sawtooth to reduce breakage and loss of fibres and to help to pull fibres into parallel form, and (iv) it redesigns a cover that matches the combing roller according to the distribution of fluid field. It is beneficial to deliver fibres and to clean off impurities.

2.1.2 Funnel-shaped Fibre Conveyer

The funnel-shaped fibre conveyer is shown in Fig.3. Its function is to send the resulting fibres from the combing roller drafting system into the disc fibre collector.

It is necessary that fibres being sent in airflow should be straightened, parallelised, uniform in numbers, and separated well. However, the fibres actually contain natural crimps, and opening system is defective as well, and therefore the fibres cannot be totally straight when they fly into fibre conveyer. Hence, the form of fibre conveyer and the field of airflow should be designed reasonably to ensure fibres in a good form.

An earlier research\(^4\) showed that the speed of laminar flow was so low that the resulting drafting force was very small. Therefore, the turbulence at a high speed is applied to improve the distribution of fibres. The airflow velocity is so designed as to accelerate along the fibre conveyer so that the fibre stream in delivery is stretched, even, and attenuated.

When the fibre stream is continuous in fibre conveyer, the following equation holds good:

\[ n_1v_1 = n_2v_2 = \ldots = n_iv_i \]

where \(n_i\) is the number of fibres that pass through the section \(i\) of fibre conveyer; and \(v_i\), the velocity (airflow velocity) of the fibre stream at the section \(i\) of fibre conveyer.

If \(v_i > v_{i-1}\), then \(n_i < n_{i-1}\), i.e. the fibre stream is accelerated and attenuated. Based on the result of experiments, the optimum air contraction ratio (area of inlet/area of outlet) of funnel-shaped fibre conveyer was found to be 3.75.

The studies have proved that the average velocity of airflow in this funnel-shaped fibre conveyer increases gradually. The inlet of the funnel-shaped fibre conveyer connects with the combing roller, and the distance \(\Delta\) between the outlet and the groove of disc fibre collector is 1mm (Fig. 2).

2.1.3 Disc Fibre Collector

The disc fibre collector is the core device of this spinning system. It collects the fibres away from funnel-shaped fibre conveyer, and assembles them into a smaller strand to be spun.

The disc fibre collector consists of two parts (Figs 4 and 5), one is a V-shaped eyelet groove (2) which is placed outside and can rotate around axle (1); and the other is a fixed fan-shaped air duct (3) which is under the groove with a tight fit with it. The exterior slit of the air duct just faces the V-shaped eyeleted groove. Inlet scoop (4) connects with a...
suction system that generates high speed turbulence. When the suction system operates, it is under the control of a constant negative pressure that exists on the surface of the groove. The fibres out of fibre collector will be absorbed in the eyeleted groove tightly by suction. With the rotation of the groove, an even and attenuated strand is delivered out successively.

2.1.4 Swirl Twister

A sketch of swirl twister is shown in Fig. 6 (ref. 5). As reported earlier, the swirl twister is made up of two nozzles. In the first nozzle, the diameter of filament duct is 3.5 mm, and the diameter of air duct is 1.5 mm. In the second nozzle, the diameter of filament duct is 4.5 mm, and the diameter of air duct is 2.5 mm. The first nozzle gives airflow swirling counter-clockwise at a high speed. The airflow pulls the yarn, and controls the distribution of strand in the front nip. It is beneficial to spread and separate the outer fibres, and to cause the fibres freed from the nip to wind on core yarn primarily in the first nozzle. The second nozzle jets out a clockwise airflow, the speed of which is higher than that in the first nozzle. Under the action of the two airflows in the two nozzles, the core yarn is first given false twist, and then gets detwisted with the free fibres getting wrapped or wound on it.

2.2 Test Methods

The rotational speed of combing roller is 12000 rpm, manufacturing speed is 200 m/min, and the pressures of the first and the second nozzle are 0.40 MPa and 0.70 MPa respectively. The SEM photo of disc swirl yarn is compared with those of the air-jet and rotor yarns (Fig. 7). The tensile strength, breaking elongation, and breaking tenacity were tested on YG020 type electron single yarn tensile tester, and the results are shown in Table 1.

3 Results and Discussion

Figure 7 shows that the appearance of disc swirl yarn is somewhat similar to that of rotor yarn, but it is not very even along its length. In some parts of the yarn, the fibres on the surface bind tightly, so the

![Fig. 6—Swirl twister (1—first nozzle, and 2—second nozzle)]

![Fig. 7—Appearance of three kinds of yarn (A—air-jet yarn, B—rotor yarn, and C—disc swirl yarn)]
wrapping or tangling of fibres is obvious. The inner structure of the disc swirl yarn is found similar to that of the air-jet yarn, and the core filament yarn is nearly without twist, bound by the outer fibres. The author basically feels that the drafting principle of the disc swirl spinning is similar to that of rotor spinning, while the yarn forming principle of disc swirl spinning is similar to that of air-jet spinning. Further research is needed to improve the yarn evenness and appearance.

It is observed from Table 1 that the tenacity of disc swirl core-spun yarn is about 33% lower than that of the ring core-spun yarn, while breaking elongation CV (%) is higher. This is mainly because the fibres of ring core-spun yarn are arranged much better than that of disc swirl core-spun yarn. This shows that the design and manufacture of disc swirl spinning mechanism needs to be improved. Table 1 further shows that the remaining properties of the two kinds of yarn are similar, which indicates that the quality of the disc swirl core-spun yarn can basically meet the need of the processes.

The new spinning system was compared with air-jet spinning with regard to following parameters:

**Mechanism**—The frame has a simple structure of low weight, with not many components. The separation and assembling of the fibres in drafting process are achieved separately one after the other. Hence, the quality of the yarn is easy to control.

**Force and dynamics**—Since there is no side force on the components of the drafting device, the drafting device wears little, and the drafting speed can be high.

The number of the components of drafting device is small and hence the disc swirl spinning is convenient to operate.

**Power and cost**—The drafting power is provided using compressed air. The manufacture speed is 200m/min. Therefore, this new system is cost effective or less expensive than air-jet spinning.

**Application**—At this stage of development, it is usable for manufacturing polyester/cotton core-spun yarn.

### Table 1—Comparison of yarn properties

<table>
<thead>
<tr>
<th>Quality parameter</th>
<th>Disc swirl core-spun yarn</th>
<th>Ring core-spun yarn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yarn count, tex</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>Breaking strength, cN</td>
<td>244.5</td>
<td>285</td>
</tr>
<tr>
<td>Breaking strength CV, %</td>
<td>14.43</td>
<td>14</td>
</tr>
<tr>
<td>Breaking elongation, %</td>
<td>19.6</td>
<td>20.7</td>
</tr>
<tr>
<td>Breaking elongation CV, %</td>
<td>39.05</td>
<td>27.4</td>
</tr>
<tr>
<td>Tenacity, cN/tex</td>
<td>7.48</td>
<td>11.2</td>
</tr>
<tr>
<td>Tenacity CV, %</td>
<td>14.43</td>
<td>13</td>
</tr>
</tbody>
</table>

*a* Both of the yarns are 32tex T/C core-spun yarn, and wound ratio (sheath/core) is 20/80.

4 Conclusions

4.1 A novel spinning approach ‘disc swirl spinning’, which uses combing roller drafting and swirl twisting, has been developed.

4.2 Its remarkable advantage lies in the high drafting efficiency and rapid production. Its drafting device wears little. Hence, the rapid production capability provided by the rotational speed of jet stream in nozzle can be well utilized.

4.3 The quality of the disc swirl yarn can basically meet the need of the processes.

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